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MINUTES,

MADE AT

A MEETING,

of the

PRINCIPAL

Iron Masters,

IN THE

Counties of YORK and DERBY;

At BRADFORD, June 11th, 1800.

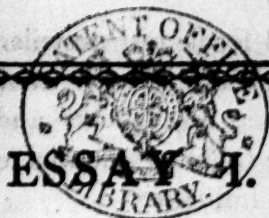
No. II.

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Delivered at Bradford, June 11th, 1800,

By the President, Mr. DAWSON, of the *Low-Moor*
Iron-Works.

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GENTLEMEN,

YOU will remember, that the subject of the present Essay is, the effect of Air and Moisture on Blast Furnaces. In order to understand the business, it will be proper to consider the nature of each of these substances separately, that from hence we may the more distinctly point out their joint or separate effects on the furnace.

By air we mean that elastic substance which surrounds this globe, and constitutes what we call the atmosphere. Like all matter, it is heavy, and possesses besides, the property of being elastic. In consequence of this, either by its own weight or by any compressure, it can be made more or less dense. This fact is pointed out to our daily observation by the Barometer.

Like every other substance air is expanded by heat and contracted by cold. It has an affinity also to a vast variety of substances. By means of this principle the odoriferous perfumes of every plant, flower or shrub, are widely de-

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fused in the air and regale our nostrils. And on the same principle the disagreeable stench arising from putrid carcasses, stagnant pools, oil, tallow, and a variety of other substances, convey their pestilential effects to all within the sphere of their influence.

But that substance to which air has an affinity, which particularly claims our attention at this time, is, moisture. It has always been a matter of curious enquiry how it happened that moisture, which is a body so much specifically heavier than air, should ascend in it? And how it came to pass, that clouds of water should be formed in the airy regions above the earth and supported there—that they should now be spread out in their variegated colours and then be dispersed—at one time descend in rain, hail or snow, and immediately after be elevated in water?

Various have been the hypotheses that have been formed, from the first dawn of philosophy to the present day, to account for the appearances; but no one has succeeded so well in these conjectures as Dr. Hamilton, who ascribes them to a mutual attraction or affinity which takes place between air and water.

This attraction is affected by the rarity or density of the air. Common atmospheric air placed within a close receiver on an air-pump, will be perfectly transparent—the sides of the glass receiver will be clean and free from moisture,—but a single stroke or two of the piston, by rarifying the air, causes it to deposit moisture upon the sides of the receiver. Let the air return and the moisture is immediately absorbed.—On the other hand, damp the sides of the receiver belonging to a condenser, inclosing air of the common density of the surrounding

atmosphere and the moisture will remain. Throw into the receiver a quantity of air, and the dense air will immediately take up the moisture and the whole will become transparent. The rarer therefore the atmosphere, the less moisture it contains, and the denser, the more.

But this attraction between air and moisture is further modified by heat and cold. Heat enables the air to dissolve more moisture, and cold disposes it to throw it out;—consequently heat increases the attraction between air and moisture, and cold diminishes it.—Hence in a morning when a thick fog covers the earth, it is immediately dispersed as soon as the sun warms the air and enables it to dissolve the water which lay intangled in it, and spread it upon the surface of the ground.—Hence too evaporation is generally more abundant in proportion to the heat of the weather, and hence a thousand appearances, which daily strike our eyes, depending on this principle, were it our present business, might easily be explained.

We have said before, that the attraction between air and moisture is diminished by its being made rare, and increased by its being made dense;—We have also said, that heat increases that attraction and cold diminishes it:—Now it is evident, that when heat is applied to such an elastic body as air, it must rarify it, and consequently at the same time that the attraction between air and moisture is increased by heat it will be diminished by the rarefaction it occasions. What proportion these two circumstances bear to each other in increasing or diminishing the affinity between air and moisture, has, I believe, never yet been determined. But the prevalence of each principle in different circumstances has been matter of observation to every Philosopher, and abundantly sufficient to establish the sentiment.

You will give me leave further to remark concerning the attraction between these two substances ; that in proportion as the air takes up moisture, its attraction for it seems to diminish, and *vice versa*, its attraction for it increases as the quantity it contains is less. This is consonant to the laws of elective attraction in every instance. Hence in the summer season when the weather has been for a considerable time dry, evaporation does not proceed with its usual vigour, notwithstanding the temperature of the air is considerably high ; and in the winter, when a considerable descent of water has taken place, evaporation proceeds rapidly, notwithstanding the weather is remarkably cool. Perhaps it may be owing to this, that in frosty weather evaporation is very quick, and hence the practice and phraseology of the Laundry Maids when they hang out their new washed linen in a winter's evening to let the frost nip the water out.—Be it owing to whatever cause it may, it is a certain fact, that in frosty weather the air is particularly greedy of moisture ; and, what is remarkable, it will take it even from ice. Dr. *Boerhaave* hung up a piece of ice in a frosty night, and found in a small space of time it lost considerably of its weight.

Water, or what we have thus far called moisture, was formerly esteemed an elementary substance. But later experiments have found it to consist of two, what modern chemistry calls oxygen and hydrogen. Subject water to a red heat in an iron vessel and the decomposition takes place. The oxygen part of the water is seized by the iron and it becomes oxygenated and the hydrogen part assumes a gaseous form and flies off in hydrogen gas, or what Dr. *Priestley* calls inflammable air. Put hydrogen and oxygen gas into a receiver, and either by an electrical spark, or flame from any inflammable body, set the hydrogen gas on

fire, and as it burns it absorbs the oxygen gas and the product is water. This proof is both analytic and synthetic of the composition of water. From water we can make hydrogen and oxygen gas, and from the union of these two gasses by combustion we can form water. This is the doctrine of the French Chemists, and it is pretty generally received as a just explanation of the facts.

Give me leave to make one general observation more, and we shall then be able fully to understand every thing that will be said on the principles to be advanced on the effects of air and moisture on blast furnaces. From a vast variety of experiments the Chemists are led to conclude, that all bodies in different degrees of temperature and under different pressures may be made to assume the state of a solid, a fluid and an elastic vapour. Under the common temperature of this climate and the common pressure of the atmosphere, we find different substances assume very different states. Metals and a variety of other substances are commonly solid. Water, quicksilver, spirits of wine, &c. are commonly in a fluid state, while air is an elastic vapour. But all these bodies under different temperatures and different pressures are made to change their appearances and assume a different nature. An additional quantity of heat will melt metals and make them fluid, and a still greater degree of heat will cause them to fly off in vapour. Water, quicksilver, and spirits of wine are rendered solid by being deprived of heat, and can easily be made elastic vapour by a sufficient addition of the same element. And even the air itself, by pressure and a degree of cold sufficiently intense, may, by parity of reasoning, be brought into a fluid and even into a solid state.

But what I mean particularly to remark, as applicable to our present subject, is, that in all these different states under the same temperature, each body contains within itself a very different quantity of heat; and in passing from one state to another, they either give out, or take in, a very considerable portion of heat, which, before this change, could not be discovered by the thermometer. Let us take for an example, to illustrate what we have said, water, one of the most familiar substances we have. In the act of being changed from ice to water, it takes up a large quantity of heat to make it fluid, and which does not at all increase the temperature of the water into which the ice is changed. When it is changed again from a fluid to steam, after the water comes to the boiling point, it absorbs a large quantity of heat in being changed into steam, without any alteration of temperature in either the water or the steam. Reverse these circumstances and the direct contrary effects take place. Change steam into water and water into ice, and at each change a large quantity of heat will evolve, which becomes discoverable by a Thermometer. Dr. Black first discovered this important fact and he called this heat, latent heat, because in its different states it lay concealed in the body that absorbed it without being discoverable by the thermometer.

Take a small piece of candle and put it on a small piece of wood and it will swim on the top of a trough of water. Light it and place over it a close receiver, which will be full of air of the common density and quality of the atmosphere. The candle in these circumstances will burn a considerable time and as it burns the water will keep rising into the inside of the receiver, till the air is considerably diminished in quantity and then it will go out. If a fresh lighted candle be put into the same air it is immediately

extinguished. This experiment shews, that, whatever it was in the air that supported the combustion of the candle, it is spent, and it further shews, that it is entirely taken out of the air and has disappeared.

Upon examining closely into experiments of this kind, it was found that the common atmospheric air consisted of two parts or kinds of air, one called oxygen, which supports combustion, and which is absorbed by the burning body and rendered solid; the other called azote, which is incapable of supporting combustion, and when united together in the proportion of one of oxygen to three of azote, constitute atmospheric air. Good atmospheric air contains about 27 parts of oxygen and 73 of azote to make 100.

The oxygen, you will observe, always disappeared as the body burnt, and was fixed in the inflammable body in a solid or concrete state. If this be the case, according to the principles just laid down, the air by combustion being changed from an elastic fluid to a solid, must necessarily give out a large portion of heat, and hence arises the heat which issues from the burning body.

It is the same process that supports combustion in the blast furnace. The fuel absorbs the oxygen out of the large quantity of air that is thrown into it, and, from an elastic fluid, changes it to a solid concrete. This process, throws out a large quantity of heat and raises the furnace to the temperature that is necessary to make the several ingredients in it act one upon another, by which the metal is deposited, and the refuse goes off in dross.

Hence it appears that a certain degree of oxygen air is necessary to be thrown into the furnace, to raise it to a proper degree of temperature; that, by the action of the several materials one upon another, metal may be produced. It follows, then, that when there is a deficiency of oxygen, the furnaces will not only work slowly, but the decomposition of the materials will be imperfect, and the metal produced not only less in quantity, but inferior in quality. These facts are certain; the experience of every Iron Master, and the cause from whence they arise is equally manifest. But what are the particular circumstances that contribute to produce this cause, and how to effect an adequate remedy are matters of serious concern, but of difficult solution.—Perhaps the following thoughts may a little elucidate the subject.

If combustion depend upon the quantity of oxygen thrown into the furnace in proportion to the air that actually enters, it will follow, that any operation, either of nature or art, that lessens the quantity of oxygen in the air, will be injurious, while every operation that has a tendency to increase it, will be beneficial. The investigations of Philosophers have discovered, that every burning body on this globe, every animal that breathes, every putrid substance, and a vast variety of other operations and substances, which have an attraction for oxygen, daily devour large quantities of this kind of air. If this be true, it is astonishing that all the oxygen in the whole atmosphere is not long since destroyed. But it is matter of rejoicing, that in all the works of our Almighty Creator, there is an antidote for every poison, and a remedy for every defect. Thoughts like these led Philosophers to enquire, what operations in nature counteracted this baneful destruction of this necessary principle.

Their enquiries have found out some, and no doubt there are many more yet to be discovered. From Dr. *Priestley's* experiments on vegetation, it is highly probable, that every vegetable that grows, every plant, shrub and tree, from the moss on the barren rock, to the towering cedar on Lebanon, daily sends forth pure oxygen air to renovate the atmosphere, defiled by so many natural operations. Nay, that even the simple agitation of air, and particularly the agitation of air with water, produces the same effect.—— Hence the great importance of the herbage of the fields, the trees of the forest, the tempestuous winds, and the large reservoirs of water spread over the face of the whole globe.

But besides these purifiers of air, which I have here enumerated, I am persuaded there is a greater source of purification than even all these processes put together; I mean the action of air and moisture on one another. I am fully persuaded, that air does not in the act of spontaneous evaporation attract and absorb water in its compound state, as is commonly supposed, but that in this absorption, by some law of nature never yet investigated, the water is actually decomposed and one or both of its constituent parts converted into air, as circumstances require. The air, I apprehend, in its different circumstances, acquires a different affinity for the oxygen or hydrogen part of the water, and converts it into air according to the necessity of natural operations, and this beautiful chain of cause and effect manufactures such air as these operations require, and supports the exact harmony which universally reigns in all the works of the great governor of the universe.

Is not the hypothesis here laid down, confirmed by Dr. *Priestley's* observations respecting the purification of air, by water? According to him, air, that has been ren-

dered foul, either by an inflammable body burning in it, or by an animal breathing in it, or by any other process, is renovated merely by standing over water, and, it is very soon purified, if the air be agitated in the water. Does not this shew in the most convincing manner, that foul air can readily take from water, that principle which is necessary to restore it to its former purity, and can, at the same time, convert this principle into air? Now, this principle we know to be oxygen, and we also know, that oxygen is contained in water. If then foul air, or azotic gas, by mere agitation in water, can take from the water as much oxygen, and convert it into air, as it requires to make it atmospheric air; it follows, that, when the atmosphere, by any natural or artificial operation, is deprived of its oxygen air, it can readily supply the defect from the lakes, rivers, and seas, that are interspersed over the face of the whole globe, and, by the agitation of the wind, this necessary ingredient can readily be restored.

In reflecting on these circumstances, I had no doubt in my own mind, with respect to the truth and importance of the hypothesis; but one objection struck me very forcibly. If the component parts of water and air had been the same, they would at once have supplied each others wants in a direct and easy way. But unhappily water was said to consist of oxygen and hydrogen, and air of oxygen and azote. Now atmospheric air will perhaps be as injurious to be deficient in azote as in oxygen. Supposing this deficiency to occur, how shall it be remedied?

While in this uncertainty the Philosophical Magazines for *March* and *April*, came to my hands, and there it is said, that Dr. Girtanner, had discovered that atmospheric air, did not consist of oxygen and azote, as the French

chemists maintained, but solely of hydrogen and oxygen, and that in atmospheric air, there were 21 parts out of 100, of hydrogen, and 79 of oxygen.—That when these two substances were compounded in certain proportions, they formed azote, but that when more oxygen entered into the composition, the compound became atmospheric air, of more or less purity according as the oxygen part abounded.

Consistent with this discovery, Dr. *Priestley*, had long since found that inflammable or hydrogen air, merely by standing over water, in some instances lost its inflammable principle, and in others became pure atmospheric air; and that this process was greatly accelerated by agitation. He also found, that pure oxygen air, by the same process, was reduced in its quality to atmospheric air. These facts, to the Doctor at that time wholly unaccountable, by Dr. *Girtanner's* discovery, meet with an easy solution. The hydrogen air, by being agitated in water, unites to the oxygen of the water, and converts it into air, sometimes in such exact proportion as to form azote, and sometimes in such increased proportion as to form atmospheric air; and by the same process the oxygen air takes the hydrogen part of the water, converts it into air, and so becomes atmospheric air. These facts do not only mutually explain one another, but, I apprehend, give a high degree of probability to the hypothesis above laid down concerning spontaneous evaporation.

There are also some experiments mentioned in the same Magazines, as made by *Humboldt*, which will be easily explained by the principles here laid down, and which will at the same time tend to elucidate and confirm the hypo-

thesis here maintained. This chemist, by experiments with the Eudiometer, is said to have discovered,

FIRST. That the quantity of oxygen contained in atmospheric air, decreases, according to the abundance of clouds, fogs, rain and snow, but that it increases during dry and serene weather. These facts, I apprehend cannot be explained on the common hypothesis respecting spontaneous evaporation. A dry air, according to this hypothesis, is always exhibited when the water supposed to be contained in it, is in perfect solution with the air. This complete solution of the water in the air, be the quantity dissolved more or less, always protects the water from the hygrometer, and therefore it is called dry. But as soon as the water is precipitated in clouds, fogs, rain or snow, it then affects the hygrometer, and is called moist. But on the common principles of spontaneous evaporation, what difference in the quantity of oxygen air, can water held in solution, make in atmospheric air, in the different situations in which it is placed? Water is not oxygen air; and therefore, whether it is dissolved in the air or only intermixed with it, it still retains its distinct characteristic qualities, and can neither increase nor decrease the quantity of oxygen air in the atmosphere.

It was reflecting on this very circumstance, that led me to adopt the hypothesis which I have above attempted to establish, and upon which the solution is perfectly easy. If evaporation consists in decomposing water and converting it into air; and if the air, in this act of decomposition, converts only such part of the water into air as is necessary to make it of a proper degree of purity; and if a deficiency in the oxygen part is generally experienced, it will follow, that a dry air will have its oxygen part increased, and that

this increase will generally depend upon the degree of evaporation. And for the very same reason, as soon as this dry air, by the common laws of nature, is decomposed, and forms clouds, fogs, rain or snow, a deficiency in the quantity of oxygen must of course take place ; which is at once discovered by its effects on animal and combustible bodies.

SECONDLY. The same author also discovered, that in the summer season, or from *April* to *November*, there was a deficiency of oxygen in atmospheric air, in different proportions, varying from 290 to 236, This observation also precisely corresponds with fact. It is sometimes experienced in a very high degree in our blast furnaces.

But admitting this fact, there will be a difficulty to reconcile it to the principles of evaporation here attempted to be established. In hot weather it is generally believed, that evaporation proceeds with vigour, and consequently, if it consists in converting such of the component parts of water into air as at the time are necessary to render it of a proper quality for the purpose of life, how comes it that at this season of the year, the equilibrium is destroyed and that atmospheric air contains less oxygen than usual? The objection, made by my friend Mr. *Mushet*, of the *Clyde* Iron Works, is very fairly urged, and it will be proper to meet it in its full force. Perhaps the following thoughts may have a tendency to reconcile the appearances.

Heat always rarifies air, and consequently, as far as this effect goes, as we have formerly observed, will prevent evaporation. Tho' therefore evaporation, be promoted by heat, yet, on account of the rarity it produces in the air, the quantity may not be so great as is generally supposed, and the scarcity of water at this time may probably arise as

much from the want of a supply, as the actual quantity taken away.

Besides it seems conformable to appearances, that atmospheric air, when it is rare, has actually a less proportionable attraction for the oxygen part of the water, than the hydrogen, and the contrary, when it is dense. Perhaps too, a difference in temperature may have some effect.—Hence the air being rarified by the summer's heat, may attract a greater proportional quantity of hydrogen, from the water, than oxygen; and the dense air of the winter, a greater proportional quantity of oxygen than hydrogen.—And for the same reason, when the air in the superior regions deposits moisture, it will form that moisture with a greater proportional quantity of oxygen than hydrogen. The hydrogen air which is said to abound in these regions, will easily attract oxygen from air thus circumstanced, and by a process yet unknown, the two substances will unite and form water. Consistent with this observation, when *Garnerin* ascended in a balloon over *Paris*, to the height of 669 toises, he brought down with him, a bottle of the air, with which he was there surrounded; and *Humboldt*, in examining it by the Eudiometer, found it to have considerably less oxygen in its composition than even the air in *Paris*. *Philo. Mag. vol. 1. p. 333.*

Water formed in the superior regions, seems to be in a perfectly neutral state, with respect to the air from which it comes. It descends in it without imparting its oxygen, notwithstanding the air in which it descends, is well known to be deficient in this principle.—If these suppositions be true, they assign the most satisfactory reason, why the air in winter, whatever be the state of evaporation, should be more oxygenated than in summer; and consequently more friendly to combustion and the breathing of animals.

Add to these observations, That the heat of summer promotes putrefaction both in animal and vegetable substances, and in this state, it is well-known these substances send forth a considerable quantity of azotic, carbonic acid, and hydrogen gasses, each of which, even in small quantities, will considerably diminish the purity of the air.—

An increase of temperature also increases the attraction of those substances which have an affinity for oxygen. Oil, tallow, and all unctuous substances, become sooner and to a greater degree rancid, in warm than in cold weather, which is caused by their greater attraction for oxygen, which enables them the more readily to take it out of the atmosphere. But in winter time all these circumstances are changed, and their effect upon atmospheric air is apparent.

Give me leave further to remark, That the greatest deficiency of oxygen is experienced in the summer season, when the weather is calm and little circulation of air takes place. In these circumstances, tho' evaporation may proceed with vigour, on account of the heat of the weather, yet the atmosphere in general, will not so readily partake of its effects. The fact will be, that the air over lakes, rivers, and especially seas on account of their extent of surface, will be highly oxygenated, but for want of circulation, it will hang over the waters without being able to communicate, in a beneficial degree, its salutary influence to the surrounding air; and, being itself confined over the water, by the calmness of the weather, the surrounding air cannot approach to receive purification. But we all know, that as soon as the circulation of the air takes place, the circumstances change, and the air becomes more pure.

From some or all these causes, I apprehend, evaporation in the summer season, may be equal or even superior to what takes place in the winter, and yet the comparative quantity of oxygen in the air may be very different. If therefore in the summer season there be actually such a proportionable deficiency in the air as *Humboldt* discovered, it accounts at once, in the most satisfactory manner, for the working of our furnaces, and the various appearances in the state of our metal, which we all experience.

THIRDLY. It is further remarked by the same writer, That the air is more full of oxygen on the sea than over the land. This, at the same time that it confirms the sentiment just advanced, is easily explained by the theory here attempted to be supported. The sea is the great source of evaporation. Its constant motion, extent of surface and distance from contaminating causes, afford to the air the best opportunity of supplying itself with this revivifying principle. Hence, in a dead calm, the air must hang over the sea highly loaded with oxygen, and hence too the salutary effects of sea breezes.

FOURTHLY. It is yet further observed in the same paper, That the air on elevated situations contains less oxygen than over low grounds. This is perfectly consonant to the theory above stated. Lakes, rivers and seas, from whence the air derives its oxygen, are generally on a low level. As soon as the air is oxygenated, it becomes specifically heavier, and consequently has a tendency to remain in the valley. Hence a dry air always raises the barometer, and a moist air causes it to fall. Hence too the difficulty of breathing, of which every one complains, in a moist season, and on the tops of very high mountains.

These experiments were made with the Eudiometer, and the different proportional quantity of oxygen in the air, circumstanced as above stated, exactly ascertained by this instrument, and this difference being considerable, corresponding exactly with our experience, and directly accounted for on the principles of evaporation above stated, at once confirm the facts, and give a high degree of probability to the sentiments here advanced.

Now, if the above experiments be true, you will easily see that azotic gas, atmospheric air and water, consist of hydrogen and oxygen, differently proportioned, and that these two substances are thus capable of being united without at all destroying the compound; and that being united in these different proportions, we can easily account for the different appearances which in our operations daily take place. We can assign a very good reason why air is generally so much more advantageous to a blast furnace when it is dry than when it is moist—why it should be better in vallies than on the tops of mountains—In winter than in summer—At sea than on land. Now, in all these different degrees of purity, the air is exactly the same in all its essential properties, differing only in its use according to the proportion of its component parts.

Experiments respecting water have never yet been made with a particular view to the sentiments here advanced, and, for this plain reason, because I do not know they were ever advanced before. But I have no doubt but water under different degrees of evaporation, and in different circumstances, will be found to contain in its composition, different proportions of its two constituent parts. When much moisture, for instance, has fallen, experiments may discover that the proportion of oxygen will be

increased. When evaporation has been long continued, the hydrogen will be more abundant; and perhaps a difference will be found in the proportion of oxygen, under a long continued evaporation in the summer season, to what it will be under the same circumstances in the winter. At least, these are direct inferences from the above method of reasoning, but experiments are wanting to confirm or confute the supposition.

The facts however are rendered probable from the different results that have arisen from the several experiments that have been made on the composition of water. The proportion of hydrogen and oxygen, as component parts of water, has frequently been found variable. The experimentalists have never once thought that the composition might be different in different circumstances; but whatever exceptions to preconceived notions have been found, they have always been applied to the inaccuracy necessarily attendant on experiments of so delicate a nature. A closer investigation may perhaps shew that the experiments were accurate, and the difference lay in the component parts of the water examined.

I would only further remark, that in the argumentation above adopted, the hydrogen and oxygen differently compounded, so as to form the different substances here mentioned, are in all their different states supposed to be in a perfect degree of combination. When they are united in such proportion as to form azotic gas, every particle of the air is supposed to have its just proportion of oxygen and hydrogen in perfect solution. When any quantity of oxygen gas is added, the whole mass is supposed to be improved, and that every part gets its respective share; and, when any part is taken out, the deficiency is supposed to be diffused through

the whole. Exactly in the same manner, when a quantity of oxygen is carried by a descent of moisture into water, the whole becomes intimately combined with the water into which it falls ; and, when either hydrogen or oxygen is taken out and converted into air by evaporation, every part of the water connected with it, will suffer its due proportion. So that when either hydrogen or oxygen is either taken out or put in from either air or water, no actual decomposition takes place ; so as that when either of the component parts of the substance is in part abstracted, the other must of course be separated also. The bodies are so constituted that they will easily give out a portion of one of their constituent parts, without being under the necessity of giving up either the whole or part of the other. What remains is diffused through the whole mass, and the compound is only, as it were, weaker in proportion of the part that is taken away.

Nor is this a singular property of these bodies. Water can be united to acids, and perhaps to every other fluid for which it has an attraction, in any proportion you please, and yet every particle of water will have a particle of acid united to it, and the whole will form a perfect compound. If you take 10 or 100 gallons of water, and add to it a small quantity of sulphuric acid, this small quantity will be diffused through the whole mass, and every particle of water will have a particle of acid united to it. You may add acid to the same quantity of water in any proportion you please, the same effect will follow. Every particle of water will have an additional quantity of acid united to it, and, in every stage, the compound will be complete. I need not add, that when such additions or diminutions are made, that without agitation it will require some time before a perfect diffusion can take place. You see this, in

mixing a little sugar with a cup of tea. But if no agitation was used, the same effect in time would follow. By the common laws of nature, an equal diffusion would of necessity ensue.

I have taken the liberty, gentlemen, to illustrate this principle at considerable length, not only as it is new, that you may fully understand it, but that I might view it in all its consequences, and submit the whole to your consideration. If it appear to be a philosophical whim, I trust there will be no harm. Our time may be worse spent than in being employed in philosophical trifles. If it be found true, sure I am, it will lead to great practical utility.

Give me leave, now, to enquire how these principles respecting air and moisture, will explain the several appearances that take place in our blast furnaces.

In the summer season we all know that the furnaces never work quite so well as at any other time. We also know that this has been applied to the rarefaction which the air experiences by the heat it receives from the sun. The late Mr. *Wilkinson*, to prevent this, actually made a long subterraneous passage, through which he caused all the air to go that went into his furnace, in hopes, that by this contrivance, it would be cooled, and thereby condensed before it entered the tuyere pipe. How this experiment succeeded with him, I cannot say. But in the year 1793, impressed with the same idea, I reasoned in this manner. If our furnaces work thus slowly, and make such bad metal, in consequence of the air being rarefied by the sun; any mode, by which this air can be condensed equal to such rarefaction, will correct the evil. Our safety valve was loaded at that time with two pounds upon one inch,

and I laid upon it half a pound more. This would cause a degree of condensation of the air much superior to the rarification it had received by the heat of the sun. The engine worked well, and, for five or six days, lifted up the valve. The furnaces run faster, but the metal was not at all improved.

I then varied the experiment, and, instead of throwing air into the furnaces in a condensed state, under the same pressure, I suffered it to enter in greater quantity. I took the half pound on every inch from the safety valve, and enlarged the tuyere pipe. From $2\frac{1}{2}$ inches in diameter, I made it 3, and continued it for a number of days without any effect at all upon the metal. From hence I was fully convinced that the furnaces were not injured with the air being rarified by the summer's sun.

Disappointed in this experiment, I reflected with attention on the circumstances that accompanied it. It perfectly accorded with my observations, that, in the summer time, when there was a pretty constant circulation of air, attended with brisk breezes with now and then a shower, notwithstanding the heat of the weather, the furnaces were never much injured. But when a dead calm continued for a considerable time, the heat sultry, and no rain, the furnaces suffered much indeed. In these circumstances, the heat of the weather promotes putrefaction, and the union of oxygen with oil, tallow and other substances that have an attraction for it. The dryness of the season stops vegetation. The stillness of the scene never agitates the air or disturbs the water, and the same contaminated atmosphere is circulated again and again through the furnaces, panting, as it were, for want of breath. Thus every operation that attracts oxygen out of the air, acts in

its full force ; and every circumstance that produces it, is greatly obstructed, and evaporation itself, which, I apprehend, is the great cause of renovation to the atmosphere, from the calm state of the air, must be very much impeded. The heat of the weather has a tendency to promote it; but then, as the air is rare and has no circulation, the particles next to the water, tho' loaded with oxygen, not being removed from their situation by circulating breezes, can neither communicate with the surrounding atmosphere, nor permit other particles in succession to receive purification. If in this situation, as we have hinted above, the air has a stronger than usual attraction for the hydrogen of the water, it will be pretty manifest, that when all these circumstances combine, the atmosphere must be considerably impure, and therefore that the injury done to the furnaces at this season, principally arises from a deficiency of oxygen in the air. This sentiment received a strong confirmation in my mind from observing that the furnaces in this state always worked cool, and that the metal had every appearance of an imperfect regulus.

Knowing that water contained a considerable quantity of oxygen in its composition, and that, upon being exposed to a red heat in connection with any substance that had an attraction for oxygen, the water was decomposed and formed oxygen and hydrogen gas ; it occurred to me, that if steam could, in the situation supposed, be thrown into the furnace, the red hot coaks would decompose it, absorb the oxygen gas as it rose into the higher regions of the furnace, and thereby increase the temperature of the furnace. Not having an apparatus ready for this purpose, and, recollecting that some old cinders that had been long exposed to the weather, had been very effectual in melting metal in the cupola, I determined to throw water upon the coaks

before they were put into the blast furnace. The water put upon the coaks in this manner, would, undoubtedly, in a great degree, evaporate and fly out of the top of the furnace in the form of steam, before it could be raised to a red heat. But apprehending that some part of the water, which was received into the more internal part of the coak, might remain and be changed into air, I determined to try the experiment. The trial was attended with some success. The temperature of the furnace was raised, and the metal improved. But the experiment was not long continued. In a few days a little rain fell, the air met with a pretty brisk circulation, its temperature was lowered, and that refreshing vigour, which always accompanies an increase of oxygen, remedied all defects and caused the furnaces to work well and make plenty of good metal.

Upon a future occasion, to try the effect of steam on the furnace circumstanced as above, I placed a boiler by its side, made an opening into the furnace 8 or 10 Inches above the Tuyere, and through this opening sent in a quantity of steam, at the same time the usual quantity of air was going in at the Tuyere. This effectually raised the temperature of the furnace; but the heat which the steam took from the lower part of the furnace, to be converted into air, so cooled the furnace in this part, as in a great measure to scaffold it over, and prevent its working. You will see this experiment in sufficient detail in the Philosophical Magazine, page 114. Vol 6th, therefore it is needless to repeat it here.

In the autumnal season the descent of vapour is commonly great, and, either now or at any other time when rain is abundant, it is always detrimental to the blast furnace. A change from dry to moist air, has sometimes re-

duced our charges four or five in 24 hours, and changed the metal from rich No. 1, to very indifferent No. 2.— This is easily explained on the principles before laid down. When the air descends, the atmosphere parts with a considerable quantity of oxygen, and the loose particles of moisture, entering the furnace along with the air, act precisely in the same manner as steam, and therefore materially injure the furnace.

But as soon as ever the rainy season is at an end, the atmosphere, having parted with too much of its oxygen, is eager to receive it from every river, lake or sea. Evaporation proceeds briskly. The roads swimming with water, are quickly dried up, and every reservoir contributes its portion. Cold succeeds, the circulation of the air is quick, and becomes highly oxygenated, and does its office in the furnace with increased vigour.

This give us a faint idea of frosty weather, frequently so abundant in the winter season, and shews the happy effects of it on the blast furnace.

At last the spring arrives in all its gaiety. Plants, flowers and shrubs throw out their shoots, and with them plenty of oxygen gas. Evaporation takes place precisely as it is wanted. The air is pure. Every animal rejoices in the sensation, and every combustible substance manifests the aid that it receives, by its remarkable brilliancy. Our furnaces work well, and metal is made good in quality and abundant in quantity.

Thus in every season and in every state of the weather, the principles we have here advanced, directly apply, and give an easy solution to every appearance. The air pro-

duces good effects on blast furnaces by means of oxygen, and a deficiency of this principle in the atmosphere is highly injurious. The cause of irregularity is evident and certain. It would be happy under every injurious change to be able to correct. But this is a real difficulty, for which at present, it is not in our power to point out an adequate remedy. Nature, you see, relieves herself with perfect ease. She produces a wind, she agitates the water by the air, or the descent of gentle showers, and converts that part of the water into air, in which the atmosphere is deficient, exactly to suit the exigencies of the case. But this is not within the compass of human nature.

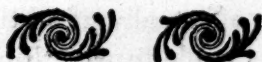
I have always thought a water receiver did this in part, and think so still. The air in a compressed state, lies exposed to the surface of the water in motion, and therefore I apprehend, will in part, renovate itself, by converting such part of the water into air, as circumstances require. It might do this more effectually, if all the air that goes into the blast furnace, was made to pass through water before it entered the tuyere. I mean to try this experiment, and am not without hopes of success.

A more complete remedy however would certainly be, if we could, either by means of heat, or some chemical solvent, extract oxygen air directly from water. If the process was cheap and could be carried on to any extent, we might easily produce that quantity of oxygen gas which would exactly suit our purpose, and throw it into the receiver in such proportion as would make it beneficial.

Black Calx of Manganese abounds with oxygen, and can easily be set at liberty in the form of oxygen gas, by sulphureous acid and heat. This will amend any small

quantity of air injured by any natural process. But the quantity in a blast furnace, will, I fear, much exceed, what in this way, we can possibly produce.

We know if steam be thrown into an iron vessel made red hot, the iron attracts the oxygen and sets the hydrogen loose in the form of hydrogen gas. Did we know of any substance that would act directly contrary to this—that would attract and absorb the hydrogen, and set the oxygen at liberty in the state of gass,—it would answer our purpose completely. But of such a substance, I am entirely ignorant. It is, however, one point gained,—that we know our wants. Our future enquiries may perhaps effectually relieve them.



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